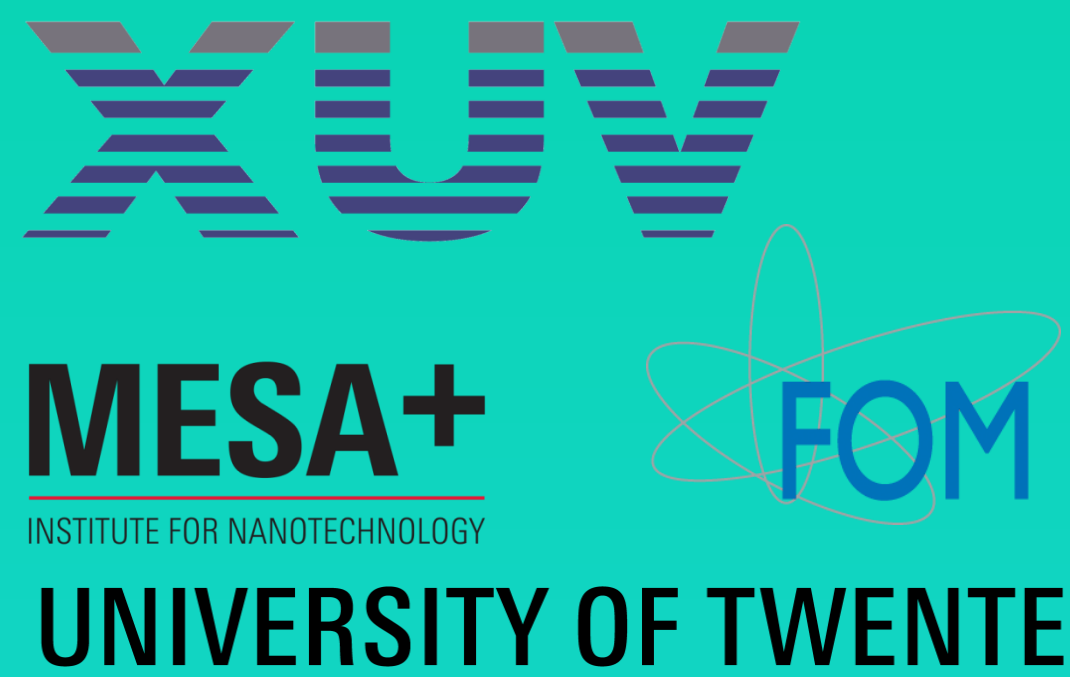


Transmission grating spectrometer for EUV source characterization from the UV to the EUV



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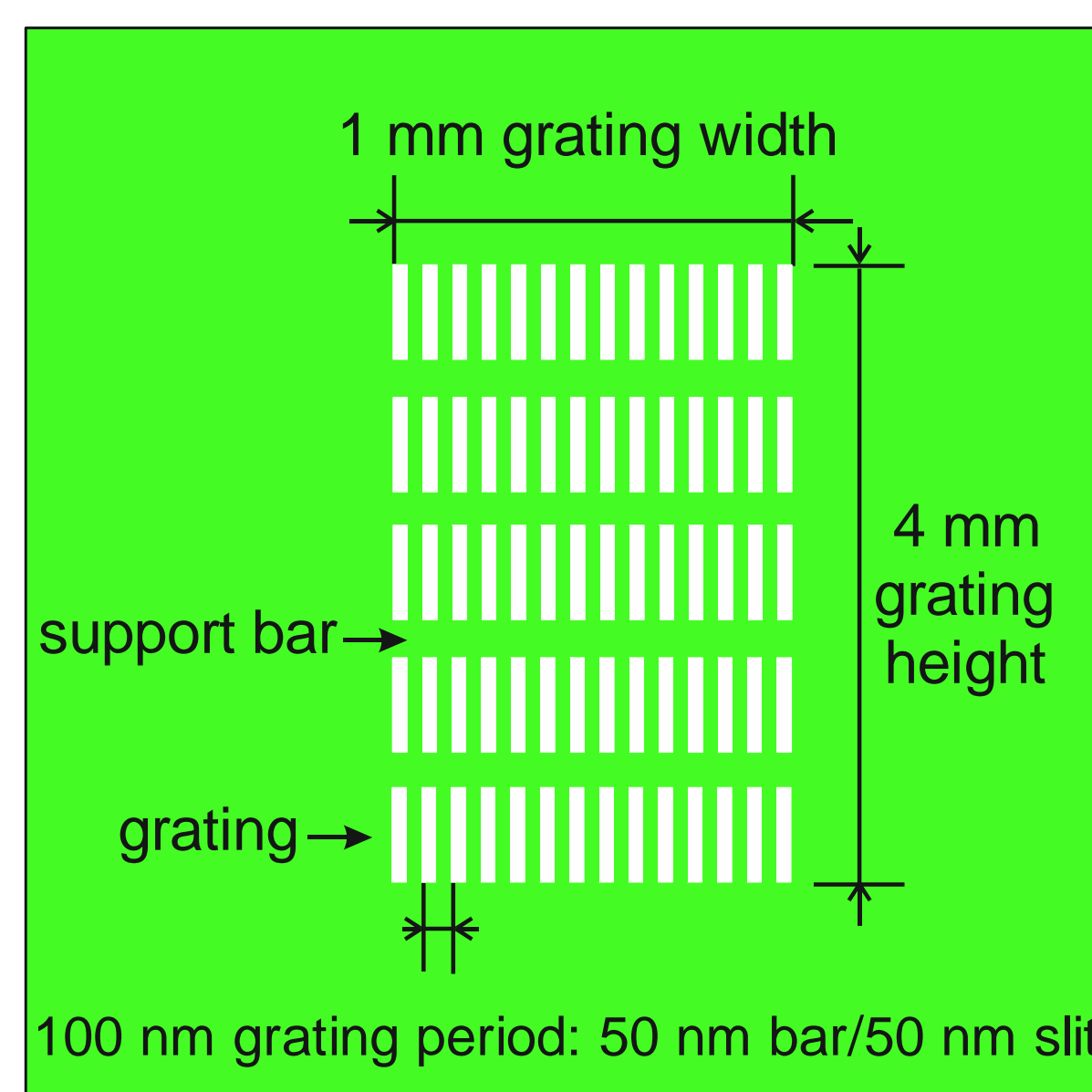
Caspar Bruineman Bert Bastiaens

Goal

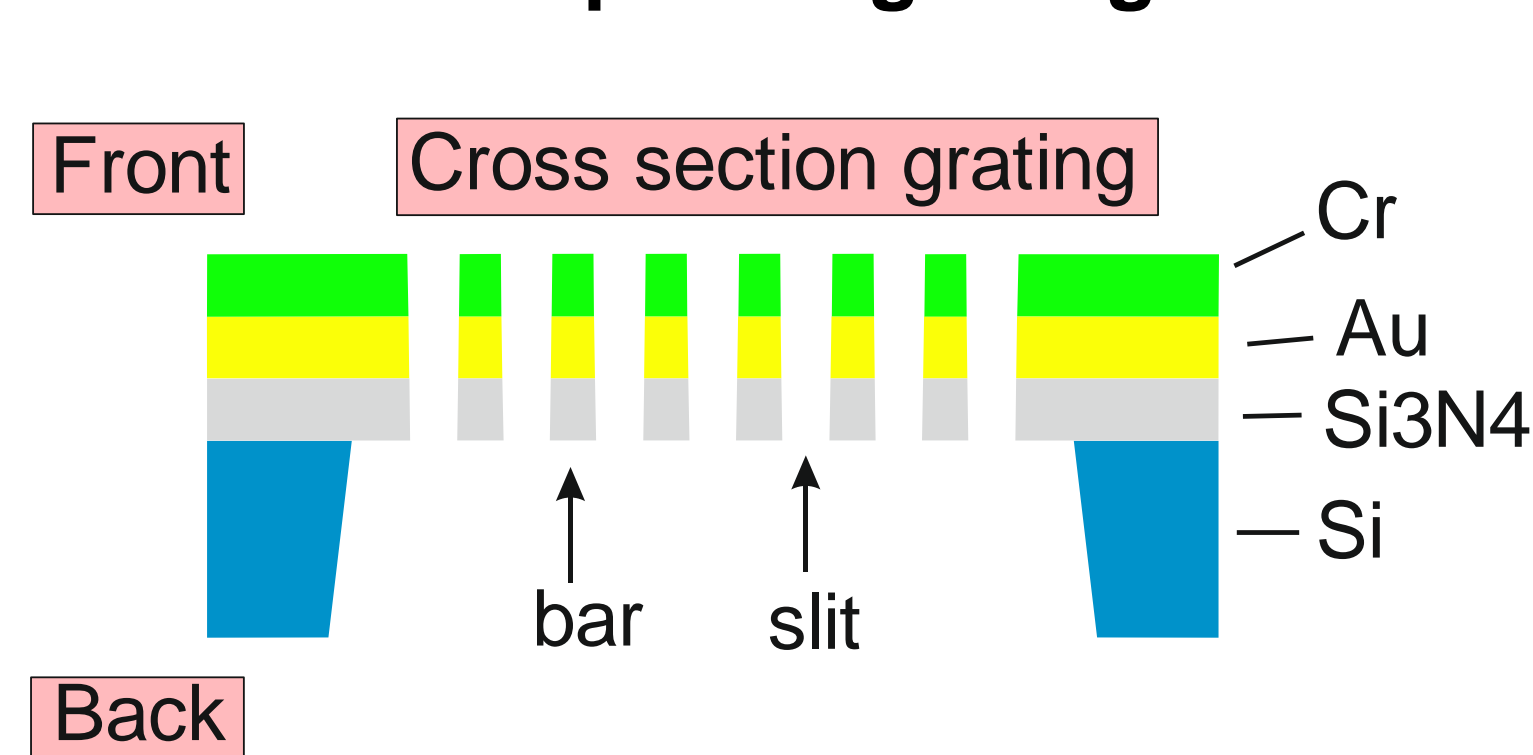
- In-band and OoB spectroscopy of EUV light sources from UV to EUV.
- Construction of portable Flying Circus spectrometer enabling cross comparison and precise VUV spectroscopic source characterization.
- Reproducible fabrication of Transmission Gratings (TG) with up to 10.000 periods/mm.
- Reliable, cost efficient, high resolution small series production.

Grating design

Front view grating

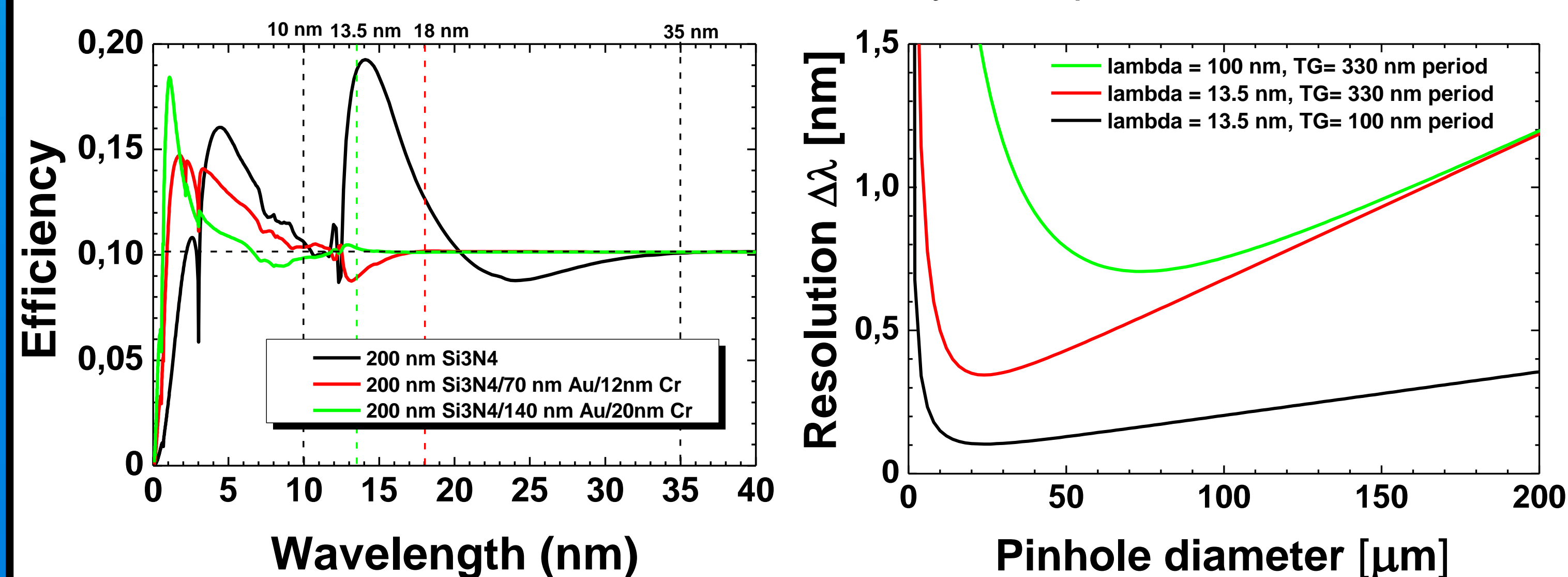


100 nm period grating



- TG in Si₃N₄ membrane coated with Au (absorber) and Cr (etch mask).
- Period/bar ratio = 0.5 (accuracy better than 10%).
- Suppression 2nd diffraction order below 0.2% of 1st order efficiency.
- Higher order suppression by filters.
- Resolution: $\lambda/\Delta\lambda \sim 100$ at 13.5 nm.
- Diffraction efficiency $\sim 10\%$.
- Available gratings on one single chip: 500, 780, 1500, 1850, 2500 mm⁻¹ and 1000 to 10.000 mm⁻¹ (incremental steps 1000 mm⁻¹).
- Large grating set provides large working range of spectrometer spanning visible (VIS) to EUV

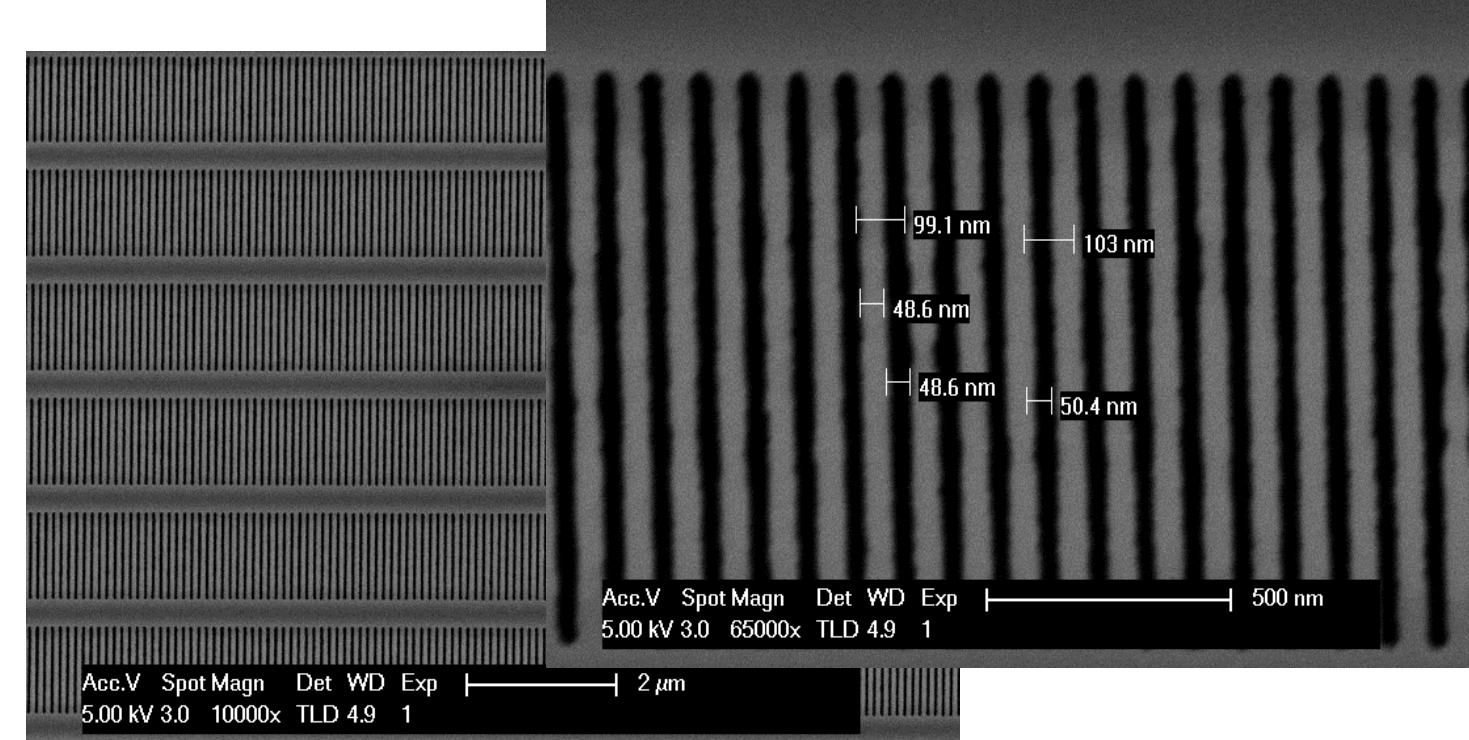
Calculated 1st order diffraction efficiency and spectrometer resolution



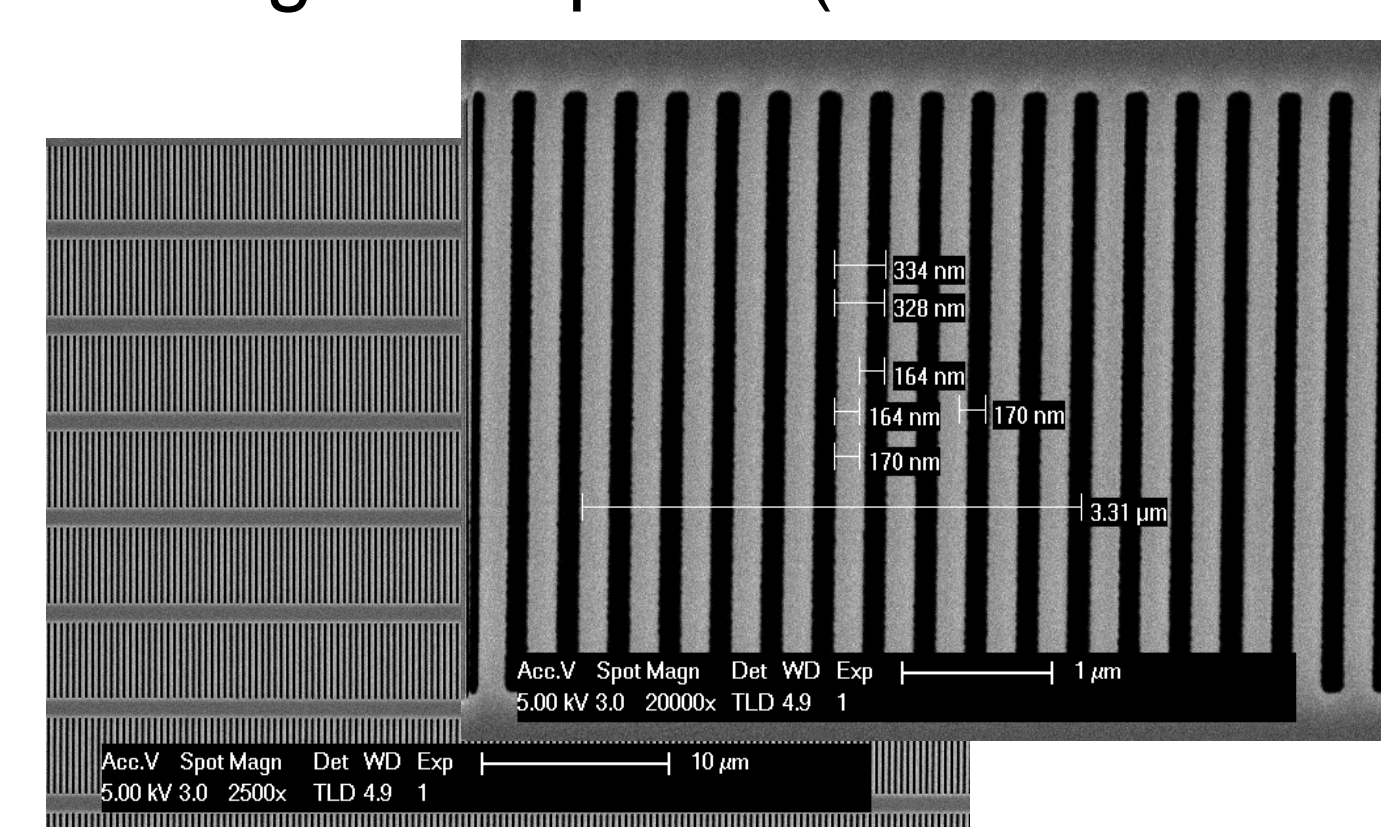
Fabrication process:

- Pattern definition by UV-NIL in resist on Si₃N₄ coated Si wafer.
- Planarization and pattern transfer down to Si₃N₄ layer by RIE.
- Deposition of Cr (etch mask) and Au layer (absorber).
- Lift-off to form etch mask and absorber layer.
- Back etch of Si by wet etching.
- Grating etching in Si₃N₄ (RIE).

Grating: 10.000 lp/mm with 50nm line features



Grating: 3000 lp/mm (165nm/165nm)

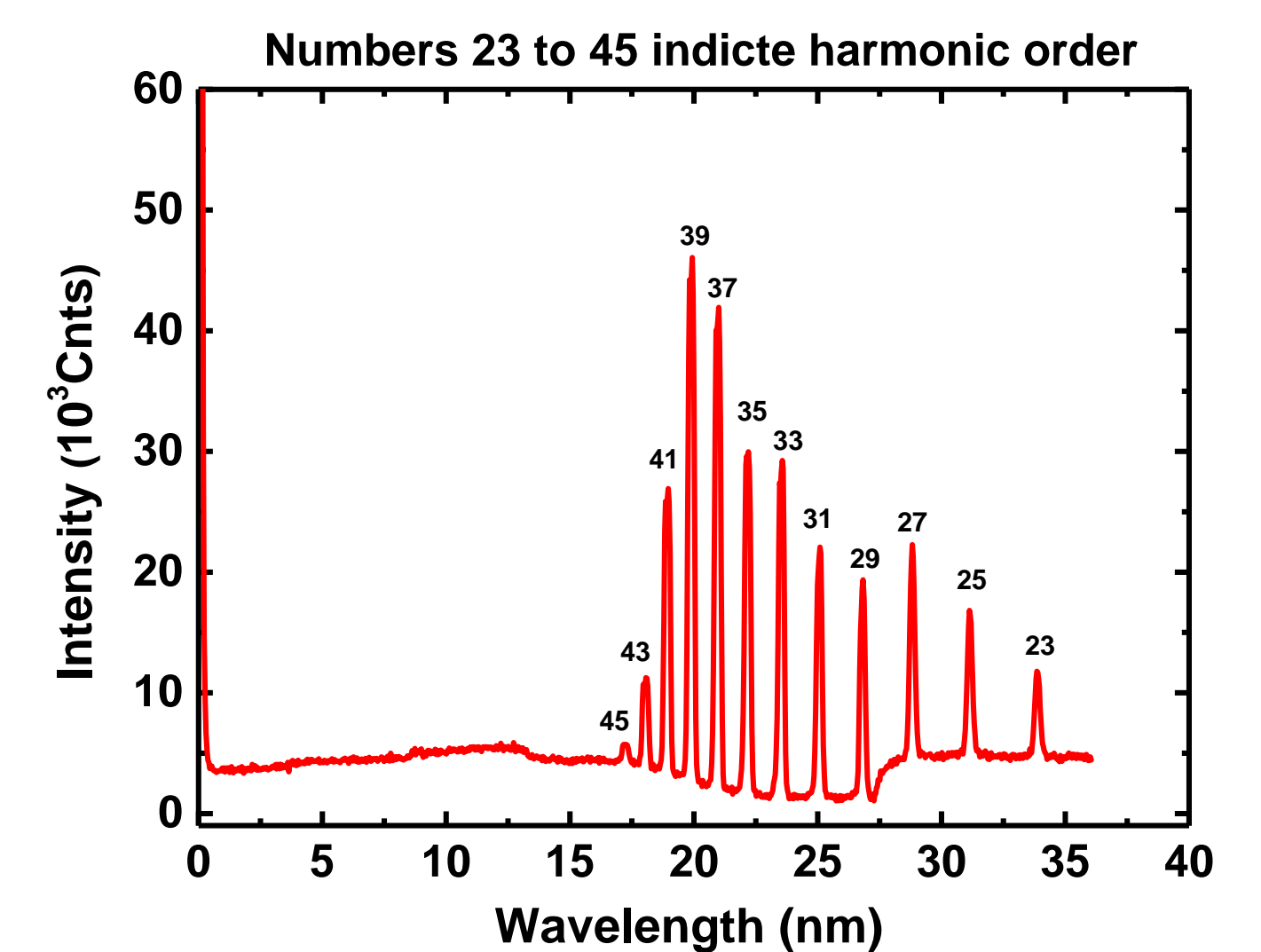


Measured spectra

Grating: 10.000 periods/mm

- Period/bar ratio = 0.5
- Al filter: bandpass 17 - 86 nm

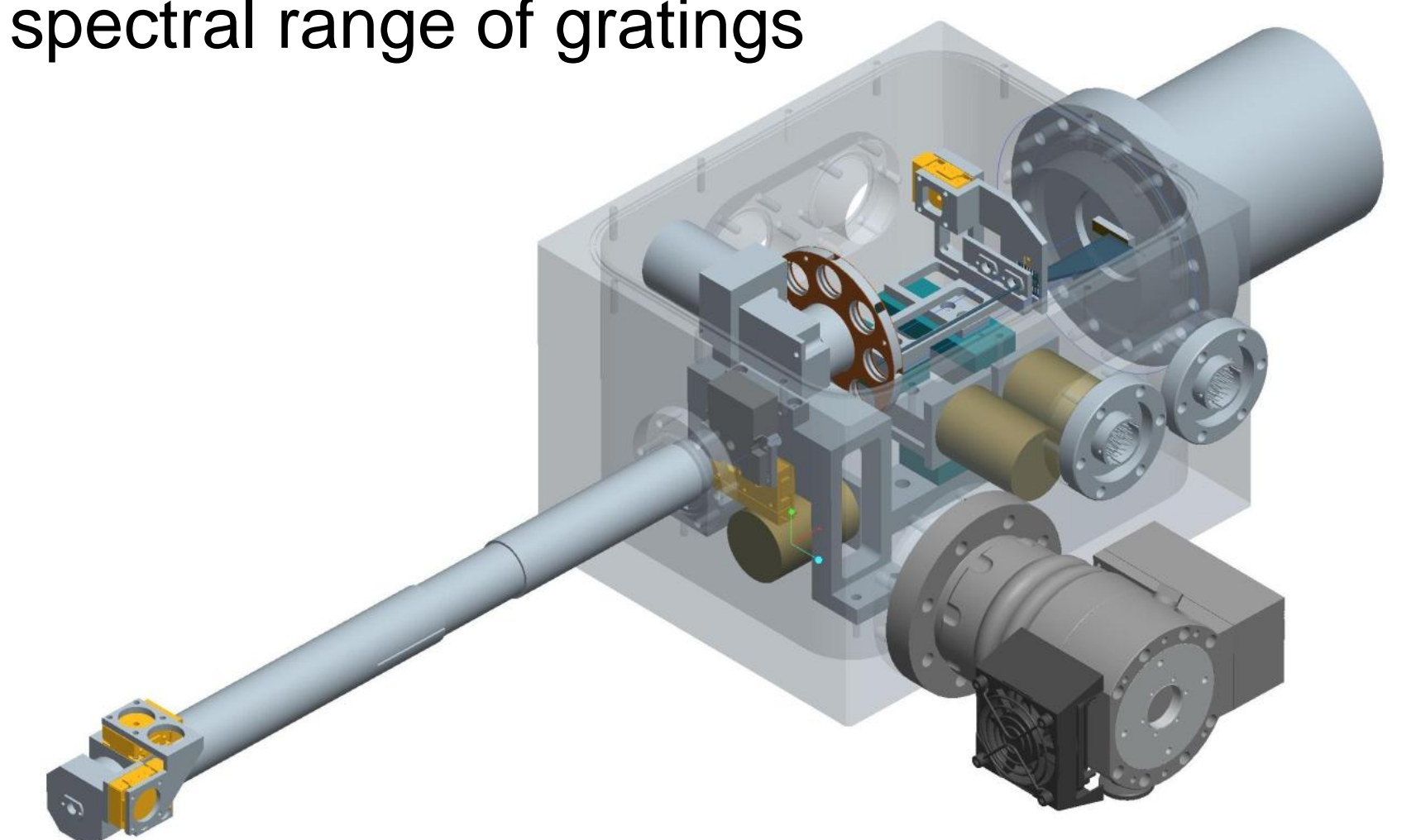
- High harmonic source
- Operating gas: Neon



Versatile multiband, transmission grating spectrometer for the VIS, VUV, EUV

- Large spectral working range: from VIS to EUV without breaking vacuum using single chip with large selection of low to high line-density gratings.
- Broadband filters with high transmission suppress higher orders and provide full coverage of free spectral range of gratings

Spectrometer design



Use as portable Flying Circus spectrometer for UV to EUV

- Absolute emission spectroscopy for EUV (6 and 13.5 nm for lithography) and soft X-ray sources (coherent High Harmonics).
- Absolute VUV out-of-band (OoB) spectroscopy for EUV light sources.

Advantages over GIS

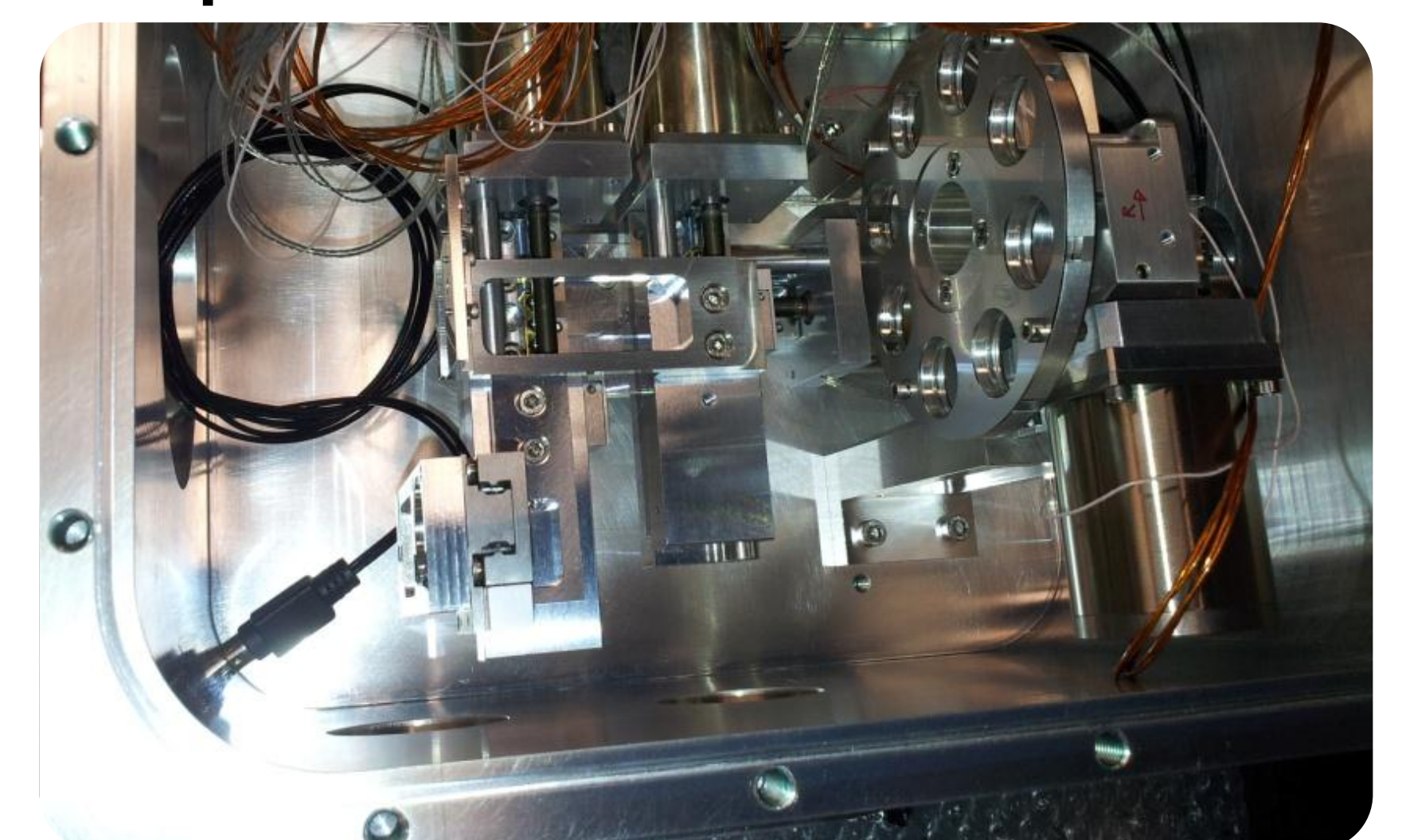
- Simple alignment, 'flat field' spectrum, straight forward calibration.
- Opaque grating: flat efficiency curve between 10 to 100 nm.
- Operation with high/low dispersion gratings allows fast switching between high resolution or large bandwidth.

Instrument features.

- Automated positioning of filters, pinholes and gratings with motorized stages allowing in-situ alignment.
- Specific configurations can be stored and retrieved at will thus making it very easy to repeat and reproduce measurements.
- Graphic User Interface (GUI) to control position of optics and process spectral images. Remote computer control via USB.
- Filter wheel accepts 8 sets of two filters.
- Integrated shutter to block light beam.
- Matched high resolution CCD camera.
- Vacuum rating: down to 10⁻⁶ mbar.
- Differential pumping option to connect to sources at elevated pressure.
- Compact size: (L) 300 x (W) 240 x (H) 200 mm.

Customization is a standard option !!!

View inside spectrometer



Summary

- We have presented the design and fabrication process for a set of transmission gratings integrated on a single chip with line densities ranging from 500 l/mm to 10000 l/mm.
 - We demonstrated reproducible pattern definition by UV-NIL and etch mask fabrication by lift-off.
 - We have shown successful fabrication of freestanding 10.000 l/mm gratings, with 50 nm line features in a Si₃N₄ membrane coated with a stack of Au and Cr.
 - We present a portable, high precision spectrometer covering a large spectral working range from the VIS to EUV, based on a large set of different line density gratings and broadband spectral filters.
- The spectrometer will be ready for source characterization in november 2013.